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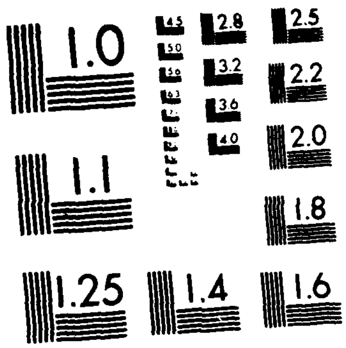

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SEATED EYE POSITIONS AND ANTHROPOMETRIC EXTREMES OF AVIATORS

By
David O. Cote
Aaron W. Schopper

BIODYNAMICS RESEARCH DIVISION

May 1986

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20. Abstract

Seated eye positions of personnel in the 1st to 5th percentile range and 95th to 99th percentile range for male stature were examined in six US Army helicopters to determine if their seated eye positions were significantly different from those of instructor pilots. In addition, the zero azimuth, outside-the-cockpit field-of-view of anthropometrically extreme personnel and instructor pilots was measured. In all helicopters surveyed, statistically significant differences were found between the seated eye positions of aviators and that of anthropometrically extreme personnel. Large differences in viewing angles were also observed in all aircraft. However, in the case of personnel in the 1st to 5th percentile range for male stature, the differences were to their advantage. In the case of personnel in the 95th to 99th percentile for male stature, field-of-view was considerably decreased in some aircraft. Further study is needed to determine what effects the reduced field-of-view for tall personnel may have on flying performance. Keywords: field of view, anthropometry; human factors engineering

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A.W.S.

PREFACE

This report is one of a series of reports on anthropometry in US Army aviation produced by the US Army Aeromedical Research Laboratory (USAARL). Information on other reports in this series may be obtained by contacting the chief of the USAARL Scientific Information Center at AUTOVON 558-6907 or (205) 255-6907.

Without the support of several personnel, this project would not have been possible. The authors would like to thank Headquarters, 1st Aviation Brigade, for their troop support coordination; the 46th Engineer Battalion, 1st Aviation Brigade, for providing a subject pool; the aviators from the 1st Aviation Brigade, and the 46th Engineer Battalion personnel who volunteered their participation as subjects; and Northrop Aviation Corporation and the Aviation Logistics and Maintenance Division of the Directorate of Industrial Operations at Fort Rucker for providing hangar space.

Several people from the USAARL aided in conducting this study. They include CPT George Mastroianni who assisted in reducing the data, 2LT Robert McCaleb who reduced the data, SFC B. J. Clark, SFC David Wells and SSG Max Bass who aided in data collection, and Mr. Larry Thomas who photographed, developed, and printed thousands of pictures.

TABLE OF CONTENTS

	PAGE NO.
List of tables	1
Introduction	3
Method	5
Aircraft evaluated	5
Subjects	5
Procedure	6
Data reduction	7
Results	9
Discussion	14
Seated eye position (SEP)	14
Seated eye position (SEP) versus design eye position (DEP)	16
Viewing angles	17
Conclusion	18
References	20
Appendixes	
A. Anthropometric profile of subjects	21
B. Anthropometric comparison of subject groups	27
C. Visual angle data	29

LIST OF TABLES

TABLE		PAGE NO.
1.	Helicopters surveyed	5
2.	Aviator sample	5
3.	Instructor pilots' eye positions	9
4.	Short subjects' eye positions	10
5.	Tall subjects' eye positions	11
6.	Instructor pilot eye position versus eye position of anthropometrically extreme personnel	12

TABLE		PAGE NO.

7.	Subjects meeting MIL-STD 850B zero azimuth visual angle criteria	13
A-1.	Anthropometric profile of short subjects	22
A-2.	Anthropometric profile of tall subjects	22
A-3.	Anthropometric summary statistics of TH-55A instructor pilots	23
A-4.	Anthropometric summary statistics of OH-58C instructor pilots	23
A-5.	Anthropometric summary statistics of UH-1H instructor pilots	24
A-6.	Anthropometric summary statistics of UH-60A instructor pilots	24
A-7.	Anthropometric summary statistics of CH-47C instructor pilots	25
A-8.	Anthropometric summary statistics of AH-1S instructor pilots	25
A-9.	Anthropometric summary profile of short subject group surveyed in each aircraft	26
A-10.	Anthropometric summary profile of tall subject group surveyed in each aircraft	26
B-1.	Anthropometric comparison of instructor pilots and short subjects	27
B-2.	Anthropometric comparison of instructor pilots and tall subjects	28
C-1.	Visual angle summary statistics for the OH-58C	29
C-2.	Visual angle summary statistics for the UH-1H	29
C-3.	Visual angle summary statistics for the UH-60A	30
C-4.	Visual angle summary statistics for the CH-47C	30
C-5.	Visual angle summary statistics for the AH-1S	30

INTRODUCTION

A concern in accepting anthropometrically extreme personnel for US Army aviation training is their field-of-view inside- and outside-the-cockpit. Anthropometrically extreme personnel in the 1st to 5th percentile for male stature (McConville et al., 1977) may sit too low in the cockpit while personnel in the 95th to 99th percentile for male stature may sit too high in the cockpit. Sitting too low in the cockpit may result in an outside-the-cockpit downward viewing angle that is unacceptable for safe flight. Sitting too high in the cockpit may result in a portion of the instrument panel being obscured by the glare shield, unacceptable viewing angles for the upper instrument panel displays, or a severely limited outside-the-cockpit upward viewing angle.

In 1969, DoD MIL-STD-1333 (Aircrew Station Geometry for Military Aircraft) defined an ideal position for the eye in a cockpit. This point, referred to as the Design Eye Position (DEP), is the reference point used in designing a cockpit. From the DEP, displays are located at desirable viewing angles, windows are placed so that minimum upward and downward outside-the-cockpit visual angles are attainable (MIL-STD-850B, Department of Defense, 1970), and cockpit controls are positioned to accommodate personnel in the 5th to 95th percentile range for stature. Thus, the cockpit is designed with the assumption that aviators will adjust the seat so that their eyes are at the DEP.

However, the existence of a DEP does not mean that aviators will adjust the seat so that their eyes are at DEP. Moroney and Hughes (1983) report that US Navy aviators sit as high as they can because a large downward viewing angle outside the cockpit is desirable for their missions. Informal conversations between combat experienced US Army aviators and the authors revealed that Army aviators tend to lower their seated eye position (SEP) in combat to obtain better protection from enemy small arms fire. Unfortunately, no one has examined flight performance as a function of SEP to determine if performance is affected by sitting at a position other than the DEP.

If aviators flying aircraft designed subsequent to 1969 do not sit at DEP and they pass their annual check rides, then one may assume that sitting at DEP is not necessary to perform the tasks required of aviators. Consequently, we should not be concerned primarily with the inability of anthropometrically extreme personnel to sit at DEP. Instead, we should determine if the SEP of anthropometrically extreme personnel is significantly different from the SEP of aviators. If it is not, we can assume that, due to SEP, the performance of anthropometrically extreme personnel should not be any different from that of aviators. A similar logic applies to aircraft designed before 1969, which includes most Army aircraft. Although no DEP existed for these aircraft, the SEP position of experienced aviators must be acceptable. However, if the SEP of anthropometrically extreme personnel is significantly different than that of aviators, then we cannot conclude anything about the potential effects of their SEP position on performance. To resolve this issue would require field trials that examine the performance of aviators placed at SEPs occupied by anthropometrically extreme personnel.

The present study was conducted to determine if personnel in the 1st to 5th percentile range, or 95th to 99th percentile range for male stature, have a SEP that is significantly different from that of aviators. In aircraft designed after 1969, the SEP of aviators was examined to determine if they sat or could sit at the DEP of the aircraft. Since zero azimuth, outside-the-cockpit field-of-view data readily was available in this evaluation, it was collected to determine if aviators and anthropometrically extreme personnel met the zero azimuth upward and downward field-of-view requirements of MIL-STD-850B (Department of Defense, 1970).

METHOD

Aircraft evaluated

Seated eye height was examined in six helicopters used extensively in Army aviation. These helicopters are listed in Table 1.

Table 1. Helicopters surveyed

Designation	Type
TH-55A	Trainer
OH-58C	Observation
UH-1H	Utility
UH-60A	Utility
CH-47C	Cargo
AH-1S	Attack

Subjects

Subjects came from two military populations. One population consisted of Army instructor pilots with a current rating in the aircraft in which they were surveyed. Throughout the this report, these instructor pilots will be representing the 5th to 95th percentile aviator and may be alternately referred to as "aviators." The number of aviators surveyed in each aircraft and their flight experience in the aircraft in which they were surveyed is presented in Table 2. An anthropometric profile of the instructor pilots is given in Appendix A.

Table 2. Aviator sample

Aircraft	Number of aviators	Mean flight time/hrs	Flight time range/hrs
TH-55A	14	2160	250-12,000
OH-58C	37	1275	350-2700
UH-1H	38	1828	120-4500
UH-60A	9	259	25-500
CH-47C	5	1660	300-3000
AH-1S	24	1775	600-4000

The second sample of subjects consisted of 18 enlisted personnel of anthropometrically extreme stature (1st to 5th percentile and 95th to 99th percentile for male stature, McConville et al., 1977). Appendix A contains an anthropometric profile of these subjects. A statistical comparison of the instructor pilots to the two groups of anthropometrically extreme personnel is given in Appendix B. With one exception, the mean seated eye height (vertical distance from sitting surface to the outer corner of the eye) of each instructor pilot group was significantly lower ($p < .05$) than that of the tall subjects they were compared against and significantly higher than the short subjects they were compared against. The one exception was in the case of the CH-47 instructor pilots. Their seated eye height was not significantly higher than that of the short subjects against whom they were compared.

Procedure

Aircraft design eye height, as described in MIL-STD-1333A (Department of Defense, 1976), is 78.7 cm above the neutral seat reference point. The neutral seat reference point is the intersection of the seat back plane and the seat pan plane when the seat is positioned in the middle of all adjustment ranges. Neutral seat reference point was determined by depressing rulers against the seat pan and the seat back, to simulate someone sitting in the seat, and taking the intersection of the two rulers as the neutral seat reference point. Design eye horizontal position is dependent on seat back angle. The greater the seat back angle, the further forward the design eye horizontal position is from the point 78.7 cm above the the neutral seat reference point. MIL-STD-1333A provides a table for determining the forward-rearward location of DEP with seat backs of various angles.

A reference photograph was taken in each data collection session. With the pilot seat positioned at the middle of all adjustment ranges, a 101.5 cm by 91.5 cm cardboard, marked off in 5.1-cm grid squares, was cut to make a template that would fit into the pilot's seat. The cardboard template was positioned in the middle of the seat on a plane corresponding to the midsaggital plane of an aviator. With the reference template taped securely in place, the DEP of the aircraft was marked on the template. Although aircraft designed before 1969 do not have a DEP, the same procedure was followed to obtain a reference point from which other measures could be made. For later use in determining upward and downward visual angles, two other points also were marked that referenced the top of the glareshield and the top of the windscreen. Other reference markers were placed around the cockpit to aid in data reduction. The camera used to photograph the reference picture was equipped with a normal lens. It was positioned at the pilot's side of the cockpit such that DEP was in the middle of the picture and the the entire cockpit and template would be included in the picture. Positive transparencies were made from the negative.

After the reference picture was taken, the template was removed from the cockpit and subjects were placed in the aircraft. Instructor pilot subjects were instructed to position the pilot seat at the point in which they normally fly and assume their normal flight posture. Short and tall subjects had the seat positioned appropriately for their statures. The seat was positioned full-up/full-forward for short subjects and full-down/full-rearward for tall subjects. In the CH-47C, the seat angle adjustment was positioned to minimize seat back angle for short subjects and maximize seat back angle for tall subjects. A picture was taken of each subject in his/her respective seat position. In all aircraft, the instructor pilot seat position was noted on a card and placed in the picture.

Data reduction

Data was obtained from pictures of each subject seated in the cockpit. To obtain the picture scale for a data collection session, the grid squares on the cardboard template in the 20 cm by 25 cm positive reference transparency were measured and their size in relation to the grid squares on the template was calculated. Once the scale of the photographs for that session was determined, the top of the glareshield and the top of the windscreen, which had been referenced on the template, could be located on the reference transparency. (These points were not always obvious in the photographs because cockpit structural supports often blocked them from the view of the lens.) The positive reference transparency was placed over the positive subject prints obtained in that session and the DEP, the top of the glareshield, and the top of the windscreen were marked on the prints.

The DEP was used as the 0,0 point of a two-dimensional Cartesian coordinate system. The front of the aircraft always was positive "x" and the roof of the aircraft always was positive "y." Thus, an aviator's eye that was forward and below the DEP had x,-y coordinates. By obtaining the x,y coordinates of a subject's pupil and applying the scale factor of the transparency (which was the same as the scale factor of the photographs since the picture of the template and the subjects were taken with the camera and aircraft in the same position), the SEP relative to the DEP could be determined.

Three lines were drawn on each subject's photograph. One line was drawn through the subject's pupil, parallel to the abscissa of the above described Cartesian coordinate system. A second line was drawn through the subject's pupil and the top of the glareshield directly in front of the subject. The third line was drawn through the subject's pupil and the top of the windscreen directly in front of the subject. The zero azimuth upward visual angle was the acute angle formed by the line parallel to the abscissa and the line to the top of the windscreen. The zero azimuth downward visual angle was the acute angle formed by the line parallel to the abscissa and the line to the top of the glareshield.

The ability of an instructor pilot to sit at DEP was determined by measuring the distance between SEP and DEP and comparing that distance to the available seat movement range. For example, if a subject's eye position was 3 cm below and 3 cm rearward of DEP and the seat could be moved $\geq$ 3 cm up and $\geq$ 3 cm forward of the position in the picture, then that subject was judged to be capable of positioning his or her eyes at DEP.

RESULTS

The eye position data obtained from instructor pilots in the six helicopters surveyed are presented in Table 3.

Table 3. Instructor pilots' eye positions

Aircraft		X axis cm				Y axis* cm		
	n	mean	(s)	min	max	mean	(s)	min	max**
TH-55A	14	3.8	(3.5)	-2.8	11.9	-5.4	(2.7)	-8.4	0***
OH-58C	37	2.0	(5.6)	-10.5	19.8	-0.8	(4.3)	-9.3	10.2
UH-1H	38	3.3	(6.1)	-9.4	14.4	-9.6	(4.9)	-17.3	4.3
UH-60A	9	-6.1	(3.8)	-11.0	0.0***	-5.8	(4.4)	-11.0	1.9
CH-47C	5	-9.2	(3.8)	-13.1	-3.3	-6.1	(5.0)	-11.5	0***
AH-1S	24	1.1	(3.0)	-6.3	6.8	-4.6	(2.4)	-10.5	0***

* +x Forward of design eye position
-x Rearward of design eye position
+y Above design eye position
-y Below design eye position

** All reported distances are in centimeters from design eye position. Although the UH-60A is the only one of the aircraft designed after the establishment of a design eye position by MIL-STD-1333A, the design eye position reference point can be easily found in any aircraft by following the procedures outlined in MIL-STD-1333A.

*** Eyes at the x or y coordinate of design eye position.

Tables 4 and 5 contain eye position data of short and tall personnel.

Table 4. Short subjects' eye positions

Aircraft		X axis	cm			Y axis*	cm		
	n	mean	(s)	min	max	mean	(s)	min	max**
TH-55A	7	5.5	(2.9)	1.9	8.9	-9.1	(4.9)	-16.5	-1.3
OH-58C	7	-6.3	(0.9)	-7.6	-5.3	-9.0	(3.9)	-15.1	-2.8
UH-1H	7	6.1	(4.5)	-0.7	14.0	-7.7	(2.9)	-11.9	-2.8
UH-60A	5	6.4	(2.4)	3.4	9.8	-6.6	(2.7)	-10.4	-3.3
CH-47C	6	0.1	(2.1)	-2.2	3.0	-1.4	(2.4)	-4.4	1.5
AH-1S	6	-6.7	(1.5)	-7.8	-3.9	-4.9	(3.4)	-9.8	-0.5

* +x Forward of design eye position
-x Rearward of design eye position
+y Above design eye position
-y Below design eye position

** All reported distances are in centimeters from design eye position. Although the UH-60A is the only one of the aircraft designed after the establishment of a design eye position by MIL-STD-1333A, the design eye position reference point can be easily found in any aircraft by following the procedures outlined in MIL-STD-1333A.

Table 5. Tall subjects' eye positions

Aircraft		X axis cm				Y axis* cm			
	n	mean	(s)	min	max	mean	(s)	min	max**
TH-55A	8	7.5	(2.9)	2.5	11.4	1.5	(2.6)	-3.2	5.1
OH-58C	9	-6.3	(4.0)	-11.3	-0.6	0.9	(3.9)	-6.9	5.0
UH-1H	9	-4.0	(2.8)	-7.0	0.0***	-8.4	(3.0)	-14.0	-4.9
UH-60A	8	-6.8	(3.6)	-13.6	-1.4	-8.2	(3.8)	-14.3	-4.8
CH-47C	8	-16.2	(2.0)	-20.0	-14.1	-14.9	(4.0)	-24.4	-11.1
AH-1S	10	-1.3	(3.0)	-6.9	2.5	-8.0	(3.8)	-14.8	-3.4

* +x Forward of design eye position
-x Rearward of design eye position
+y Above design eye position
-y Below design eye position

** All reported distances are in centimeters from design eye position. Although the UH-60A is the only one of the aircraft designed after the establishment of a design eye position by MIL-STD-1333A, the design eye position reference point can be easily found in any aircraft by following the procedures outlined in MIL-STD-1333A.

*** Eyes at the x or y coordinate of design eye position.

Table 6 contains comparisons of aviators' SEP to the SEP of anthropometrically extreme personnel. Positive x values indicate that a group of subjects had a SEP forward of aviators while positive y values indicate that a group of subjects had a higher SEP than aviators.

Table 6. Instructor pilot eye position versus eye position of anthropometrically extreme personnel

Aircraft	Mean difference in X direction (p) cm		Mean difference in Y direction (p) cm	
	short	tall	short	tall
	1			2
TH-55A	1.7 (ns)	3.7 (**)	-3.7 (*)	6.9 (***)
OH-58C	-8.3 (***)	-8.3 (***)	-8.2 (***)	1.7 (ns)
UH-1H	2.8 (ns)	-7.3 (***)	1.9 (ns)	1.2 (ns)
UH-60A	12.5 (***)	-0.7 (ns)	-0.8 (ns)	-2.4 (ns)
CH-47C	9.3 (**)	-7.0 (**)	4.7 (*)	-8.8 (**)
AH-1S	-7.8 (***)	-2.4 (*)	-0.3 (ns)	-3.4 (*)

1. All differences in centimeters

2. Results of one-way t-test:
   ns, $p > .05$
   *, $p < .05$
   **, $p < .01$
   ***, $p < .001$

Table 7 contains information regarding the ability of each subject group in each aircraft to meet the zero azimuth, outside-the-cockpit upward and downward visual angle criteria of MIL-STD-850B. Appendix C contains the actual mean upward and downward visual angle of each group in each aircraft as well as the standard deviation of the mean and the minimum and maximum visual angle observed within each subject group.

Table 7. Subjects meeting MIL-STD-850B zero azimuth visual angle criteria

	Downward			Upward		
Aircraft	IP	SS	TS	IP	SS	TS
TH-55A	all	all	all	all	all	all
OH-58C	none	none	none	36 of 37	all	all
UH-1H	11 of 38	2 of 7	none	all	all	all
UH-60A	1 of 9	4 of 5	1 of 7	7 of 9	all	all
CH-47C	none	3 of 6	none	all	all	all
AH-1S	2 of 22	none	none	all	all	all

* IP = Instructor pilot (aviators)
SS = Short stature
TS = Tall stature

Chi square analyses were performed on the data in Table 7 to determine if any significant differences ($p < .05$) existed between the percentage of people in the groups that met the criteria of MIL-STD-850B in each aircraft. The analyses revealed that significant differences did exist for downward visual angle in the UH-60A and the CH-47C. No other significant differences were found for downward visual angle in the other aircraft, and no significant differences were found for upward visual angle in any aircraft.

The UH-60A was the only aircraft in this survey with a cockpit designed around a Design Eye Point (DEP). In this helicopter, instructor pilots sat an average of 6.1 cm rearward of the DEP ($p < .005$) and 5.8 cm below DEP ($p < .005$). Seven of the nine instructor pilots surveyed could reach the DEP by repositioning their seat.

DISCUSSION

Seated eye position (SEP)

In all six aircraft surveyed, statistically significant differences ($p < .05$) were found between the SEP of aviators and the SEP of anthropometrically extreme personnel.

In the two helicopters without adjustable seats, the TH-55A and the OH-58C, a difference in SEP in the y axis was expected because instructor pilots for both aircraft had a seated eye height that was significantly lower ($p < .001$) than that of the tall subjects and significantly higher ($p < .05$) than the short subjects. In the TH-55A, short personnel sat significantly lower than aviators (mean=3.7cm, $p<.05$) and tall personnel sat significantly higher (mean=6.9cm, $p<.001$). However, in the OH-58C, while short personnel sat significantly lower (mean=8.2cm, $p<.001$) than aviators, tall personnel did not sit significantly higher (mean=1.7cm, $p>.05$) than aviators. The reason for the discrepancy between this observation and what was expected may be due to the low overhead canopy in the OH-58C. Five of the nine tall subjects in the evaluation were forced to sit with their heads bent down because the low overhead canopy prevented them from sitting in a natural position. Thus, if tall subjects were able to sit more upright, a significant difference in the y axis for SEP may have been found between the aviator sample and the tall subject group.

Aviators in the OH-58C were found to have an x-axis SEP significantly forward of short subjects (mean=8.3cm, $p<.001$) and tall subjects (mean=8.3cm, $p<.001$). In the TH-55A, aviators were found to sit significantly rearward of tall personnel (mean=3.7cm, $p<.01$). No significant difference was found between short personnel and aviator x-axis SEP in the TH-55A (mean=1.7cm, $p>.05$). The OH-58C x-axis results might be due to the posture assumed by the instructor pilots. During data collection, they were told to assume their normal flight postures. In these positions, aviators typically rounded their shoulders, moved their upper backs slightly away from the seat, and dropped their heads about 2.5 cm. This lowers and brings forward the SEP.

The implications of these results for aircraft without adjustable seats are dependent on the aircraft involved. In aircraft with few visual obstructions to limit upward and downward vision outside the cockpit (e.g., the TH-55A), SEP may not affect flight performance. However, in aircraft with larger visual obstructions that limit outside-the-cockpit viewing (e.g., the OH-58C instrument panel), a performance decrement may occur due to reduced outside-the-cockpit viewing angles.

In aircraft with adjustable seats, many of the differences in eye position may be accounted for by the seat position of short and tall subjects. All short subjects had their seat positioned in the full up and full forward position and all tall subjects had their seat positioned in the full down and full rearward position. Because the x-direction adjustment of a seat primarily accounts for leg and arm length and not eye position, the eye position of aviators was expected to be forward of that of tall subjects and rearward of that of short subjects. This was the case in all aircraft surveyed that had a pilot seat adjustable in the x direction (UH-1H, UH-60A, and CH-47C). The mean SEP x component of aviators was rearward of the mean x component of short subjects and forward of tall subjects. However, the x-position difference was not significant ($p > .05$) between short subjects and aviators in the UH-1H and tall subjects and aviators in the UH-60A.

The effects of adjusting seats vertically for anthropometrically extreme subjects were not as predictable as those resulting from horizontal seat adjustments since vertical adjustment primarily accounts for seated eye height. The highest seat position was designed to permit a 5th percentile person to have the same SEP y coordinate as a 50th percentile person with the seat in the middle of its vertical adjustment range. The lowest seat position was designed to permit a 95th percentile person to have the same SEP y coordinate as a 50th percentile person with the seat in the middle of its vertical adjustment range. Consequently, a significant difference in SEP may not be found between personnel in the 5th to 95th percentile range for male stature. Since our sample included personnel outside the 5th to 95th percentile range, the range for which most military items are designed, the mean SEP of the short subjects would be a little lower than that of a 5th percentile person with the seat full up. Likewise, the mean SEP of the tall subjects would be a little higher than that of a 95th percentile subject with the seat full down. Thus, some differences in y-axis SEP were possible between aviators and anthropometrically extreme personnel.

In the UH-1H and the UH-60A, no significant differences were observed between aviator vertical eye position and the vertical eye position of either short or tall personnel. However, in the CH-47C, which has a seat angle adjustment that affects seat height, significant differences were observed.

With the seat angle adjustment positioned to minimize seat back angle for short subjects, which also raises the seat, short subjects sat 4.7 cm higher than aviators ($p < .05$). Because the mean seated eye height of short subjects was only 2.6 cm lower than the mean seated eye height of instructor pilots, this indicates that aviators do not raise the seat as high as one may expect or the seat adjustment made for short subjects (full up vertically, minimum seat back angle) may have overcompensated for their low seated eye height. With the tilt adjustment positioned to maximize seat back angle, which also lowers the seat, tall subjects sat 8.8 cm lower than aviators ($p < .01$). Once again, the seat adjustments made for anthropometrically extreme subjects (full down vertically and maximum seat back angle for tall subjects) may have overcompensated for their seated eye height.

Unlike any of the other aircraft surveyed, the AH-1S has a pilot's seat that only adjusts in the vertical direction. Short subjects sat an average of 7.8 cm rearward of aviators ($p < .001$) and tall subjects sat an average of 2.4 cm rearward of aviators ($p < .05$). As in the TH-55A and the OH-58C aircraft without horizontally adjustable seats, aviator eye position may be forward of short and tall subjects' eye positions because of the flying posture normally assumed by aviators. In the y axis, no significant difference was observed between the vertical eye position of short subjects and aviators.

However, tall subjects had vertical eye positions that, on the average, were 3.4 cm below that of aviators ($p < .05$). This may be due to aviators positioning their seats high so that they can view the head-up display in the AH-1S. This is supported by the data in Table 3. Of the four aircraft with vertically adjustable seats that were surveyed, the standard deviation of aviator eye position in the y axis was smallest in the AH-1S (2.4 cm). Nonetheless, the vertical seat adjustment range in the AH-1S would permit tall personnel to sit at the same position as the aviators surveyed.

Seated eye position (SEP) versus design eye position (DEP)

The only aircraft surveyed that was designed after the establishment of a DEP standard is the UH-60A. A t-test showed that instructor aviators sat significantly rearward ($mean=6.1$, $p<.005$) and significantly below ($mean=5.8$, $p<.005$) DEP. Available seat adjustment range was examined to determine if the instructor pilots could sit at DEP. Seven of the nine aviators surveyed could reposition their seats in the x and y directions such that their eyes would be at DEP.

The consistency with which UH-60A aviators sat rearward and below DEP indicates that they prefer to fly with their eyes at a position other than DEP. Thus, sitting at DEP in the UH-60A may not be essential to perform the tasks required of a UH-60A aviator. Moroney and Hughes (1983) suggest that some aircraft cannot be safely operated with an aviator's eyes at the DEP. Whether or not this is true in the UH-60A is not known. However, other factors in addition to satisfactory vision determine where an aviator positions the seat and therefore his or her eyes. These include the comfort with which the cyclic and collective can be handled and the aviator's ability to make necessary reaches.

Viewing angles

Meeting the minimum zero azimuth upward viewing angles of MIL-STD-850B was not a problem for most subjects in the aircraft surveyed. However, subjects often did not meet the outside-the-cockpit zero azimuth downward viewing angle given in MIL-STD-850B. No one in the three groups of subjects met the 25 degree downward angle criteria in the OH-58C. Of particular interest in the other aircraft was the lack of compliance with the standard by aviators. A majority of the aviators did not meet the downward visual angle requirement in the UH-1H, UH-60A, and the AH-1S. Consequently, one must ask about the importance of the criteria outlined in MIL-STD-850B. However, one must keep in mind that the downward visual angle of an aviator will change while the aircraft is in flight. For example, one would find that the downward visual angle of an aviator in the OH-58C increases by several degrees once the aircraft is in flight since it is flown with the nose low. Thus, if the visual angles outlined in MIL-STD-850B are critical for performing the mission of a specific type of aircraft, the visual angles of aviators should be examined with the aircraft in a flight attitude to determine actual fields-of-view.

CONCLUSIONS

1. In aircraft without adjustable seats, the eye position of personnel in the 1st to 5th percentile for male stature was significantly lower than that of the average aviator. This meant that these personnel had a decreased downward outside-the-cockpit field-of-view in these aircraft.

2. In aircraft without adjustable seats, the eye position of personnel in the 95th to 99th percentile for male stature was significantly higher than that of the average aviator when adequate head room was available. This meant that these personnel had an increased downward outside-the-cockpit field-of-view in these aircraft.

3. Seated eye position (SEP) is not likely to affect flight performance in aircraft with few visual obstructions to limit upward and downward vision outside the cockpit (e.g., TH-55A). In aircraft that have large visual obstructions limiting outside-the-cockpit viewing (e.g., OH-58C instrument panel/glare shield), further research is needed to determine the effects, if any, of reduced downward or upward fields of view.

4. In the AH-1S seats (which only adjust in the vertical direction), the aviators and the anthropometrically extreme individuals all positioned their eyes at about the same vertical position, presumably because of the limited eye positions from which the heads-up display can be viewed. Since all subjects could obtain the same eye position as the aviators in this aircraft, their flight performance due to SEP should not be different from that of current AH-1S aviators.

5. In the AH-1S, the downward field-of-view of all personnel surveyed did not meet the requirements cited in MIL-STD-850B.

6. In the UH-1H and the UH-60 (which do not have heads-up displays, but do have seats that adjust vertically and horizontally) no significant differences in vertical eye position (i.e., eye height) were observed between aviators and anthropometrically extreme personnel.

7. The horizontal eye position of short personnel in the UH-60A was significantly forward of the average aviator's eye position. This made their outside-the-cockpit field-of-view larger than that of the average aviator.

8. The horizontal eye position of tall personnel in the UH-1H was significantly to the rear of the average aviator's

position because tall people tended to horizontally position the seat further back to compensate for their longer-than-average extremities. As a result their outside-the-cockpit field-of-view was reduced by the instrument panel and overhead visual obstructions. This is a potential problem for tall personnel whenever seats are horizontally adjustable.

9. In the UH-1H and the UH-60A, the vertical seat position for tall personnel was changed easily without any reach compromises so that their vertical eye position was the same as that of the average aviator.

10. In the CH-47 (which has a seat-angle adjustment in addition to a vertical and horizontal adjustment), differences in vertical eye position were observed between the average aviator and anthropometrically extreme personnel. However, the small number of aviators surveyed in this aircraft and their relative shortness should be taken into consideration in interpreting these results.

11. Tall personnel in the CH-47 were found to have a SEP below and to the rear of the average aviator's SEP in that aircraft. As in the UH-1H (which also has horizontally adjustable seats), the downward outside-the-cockpit field-of-view of tall personnel was reduced in the CH-47C, but to a greater degree.

12. Short subjects in the CH-47 had a mean SEP above and forward of the average aviator's SEP. Their outside-the-cockpit field-of-view was greater than that of the average aviator.

13. In the UH-1H and the AH-1S, short personnel may have pedal control reach problems when they position the seat in the full up position. A study by Schopper and Cote (1984) revealed that some short personnel may not be able to input full pedal in the AH-1S when the seat is adjusted so that they can view the heads-up display.

14. What effects reduced fields-of-view have on flight performance are unknown. Only field performance studies in which aviator's eyes are positioned in the same SEP's as those of anthropometrically extreme personnel could determine those effects.

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APPENDIX A

Anthropometric profile of subjects

Table A-1. Anthropometric profile of short subjects

Subject	Stature cm	Seated eye height cm	Buttock to heel length cm	Functional arm reach cm
1	153.4	71.7	95.6	68.1
2	152.5	70.9	95.5	67.4
3	155.9	75.6	92.0	68.0
4	146.9	69.7	90.6	71.8
5	162.5	80.1	95.7	72.3
6	161.1	76.9	103.8	76.1
7	156.4	72.8	97.8	72.0
8	158.3	73.2	103.4	79.3

Table A-2. Anthropometric profile of tall subjects

Subject	Stature cm	Seated eye height cm	Buttock to heel length cm	Functional arm reach cm
9	182.3	88.7	111.8	82.1
10	184.1	79.5	125.1	83.6
11	183.9	85.8	112.9	81.0
12	186.3	86.4	112.9	82.2
13	186.5	88.2	114.7	81.0
14	189.0	85.5	122.8	87.7
15	189.5	85.7	123.5	87.1
16	192.5	86.3	126.5	89.5
17	192.4	91.5	124.1	84.2
18	194.5	87.3	122.5	92.1

Table A-3. Anthropometric summary statistics of TH-55A instructor pilots

	Stature cm	Seated eye height cm	Buttock to heel length cm	Functional arm reach cm
n=14				
mean	179.7	77.8	112.7	82.2
s	4.7	3.5	2.5	5.2
min	168.6	72.8	108.6	69.9
max	186.1	83.8	117.6	88.9

Table A-4. Anthropometric summary statistics of OH-58C instructor pilots

	Stature cm	Seated eye height cm	Buttock to heel length cm	Functional arm reach cm
n=37				
mean	182.7	78.6	116.8	81.6
s	7.2	3.4	6.0	3.4
min	167.6	72.2	105.2	74.3
max	199.4	85.0	128.8	91.4

Table A-5. Anthropometric summary statistics of UH-1H instructor pilots

	Stature cm	Seated eye height cm	Buttock to heel length cm	Functional arm reach cm
n=38				
mean	182.6	78.9	116.1	82.2
s	8.1	3.5	6.4	4.3
min	167.6	72.0	103.4	68.6
max	198.8	85.2	130.6	90.8

Table A-6. Anthropometric summary statistics of UH-60A instructor pilots

	Stature cm	Seated eye height cm	Buttock to heel length cm	Functional arm reach cm
n=9				
mean	184.0	80.3	117.3	81.4
s	7.6	2.9	6.6	4.8
min	174.6	75.6	109.2	73.7
max	197.5	84.4	129.4	85.7

Table A-7. Anthropometric summary statistics of CH-47C instructor pilots

	Stature cm	Seated eye height cm	Buttock to heel length cm	Functional Arm reach cm
n=5				
mean	177.1	77.1	111.3	85.2
s	6.2	2.2	5.4	3.1
min	171.5	74.2	104.4	82.6
max	186.7	80.2	118.5	90.2

Table A-8. Anthropometric summary statistics of AH-1S instructor pilots

	Stature cm	Seated eye height cm	Buttock to heel length cm	Functional arm reach cm
n=24				
mean	184.3	79.5	118.2	84.2
s	5.6	2.4	5.5	3.4
min	175.3	74.7	107.2	79.4
max	195.6	85.5	129.6	92.7

Table A-9. Anthropometric summary profile of short subject group surveyed in each aircraft*

Aircraft	n	Seated eye height cm	Buttock to heel length cm	Functional arm reach cm
TH-55A	7	74.2	97.0	72.4
OH-58C	7	74.2	97.0	72.4
UH-1H	7	74.5	97.7	71.9
UH-60A	5	72.4	95.9	71.7
CH-47C	6	74.5	95.9	71.4
AH-1S	6	73.2	97.2	72.4

Table A-10. Anthropometric summary profile of tall subject group surveyed in each aircraft*

Aircraft	n	Seated eye height cm	Buttock to heel length cm	Functional arm reach cm
TH-55A	8	87.2	119.6	85.7
OH-58C	9	86.2	120.6	85.4
UH-1H	9	85.9	119.2	85.2
UH-60A	8	85.6	120.1	85.5
CH-47C	8	86.6	120.1	85.1
AH-1S	10	86.5	119.7	85.1

*All numbers are mean values. Due to scheduling constraints with the anthropometrically extreme subject pool, not all subjects were available when each aircraft was surveyed.

APPENDIX B

Anthropometric comparison of subject groups

Table B-1. Anthropometric comparison of instructor pilots and short subjects

Aircraft	Seated eye height cm	Buttock to heel length cm	Functional arm reach cm [1,2]
TH-55A	3.6(*)	15.7(***)	9.8(***)
OH-58C	4.4(**)	19.8(***)	9.2(***)
UH-1H	4.4(**)	18.4(***)	10.3(***)
UH-60A	7.9(***)	21.4(***)	9.7(**)
CH-47C	2.6(ns)	15.7(***)	13.8(***)
AH-1S	6.3(***)	21.0(***)	11.8(***)

1. The numbers in this table are differences between short subject and instructor pilot group means. Each difference was obtained by subtracting a short subject group mean for an anthropometric measure from an instructor pilot group mean.

2. Results of one-way t-test:
   - ns, $p > .05$
   - *, $p < .05$
   - **, $P < .01$
   - ***, $p < .001$

Table B-2. Anthropometric comparison of instructor pilots and tall subjects

Aircraft	Seated eye height cm	Buttock to heel length cm	Functional arm reach cm[1,2]
TH-55A	9.4(***)	6.9(**)	3.5(ns)
OH-58C	7.6(***)	3.8(*)	3.8(**)
UH-1H	7.0(***)	3.0(ns)	2.9(*)
UH-60A	5.3(***)	2.8(ns)	4.1(*)
CH-47C	9.5(***)	8.8(**)	-0.1(ns)
AH-1S	7.0(***)	1.5(ns)	0.9(ns)

1. The numbers in this table are differences between tall subject and instructor pilot group means. Each difference was obtained by subtracting an instructor pilot group mean for an anthropometric measure from a tall subject group mean.

2. Results of one-way t-test:
   ns, $p > .05$
   *, $p < .05$
   **, $P < .01$
   ***, $p < .001$

APPENDIX C

VISUAL ANGLE DATA

Table C-1. Visual angle summary statistics for the OH-58C

Subject group	n	Upward cm mean	(s)	min	max	Downward cm mean	(s)	min	max
Pilot	37	41.9	(10.0)	15.5	65.0	17.2	(3.5)	8.0	24.0
Short	7	53.6	(4.3)	46.0	59.0	11.8	(3.3)	6.0	16.5
Tall	9	40.6	(5.8)	33.0	51.5	19.6	(2.5)	15.0	24.0

Note: No visual angle data is provided for the TH-55A because upward and downward vision is unrestricted in this aircraft.

Table C-2. Visual angle summary statistics for the UH-1H

Subject group	n	Upward cm mean	(s)	min	max	Downward cm mean	(s)	min	max
Pilot	38	45.1	(8.2)	29.0	60.5	21.6	(5.1)	12.0	33.0
Short	7	44.9	(5.6)	38.0	54.0	23.7	(4.5)	18.5	30.0
Tall	9	34.8	(6.2)	22.0	43.0	18.8	(2.6)	15.0	23.0

Table C-3. Visual angle summary statistics for the UH-60A

Subject group	n	Upward cm mean	(s)	min	max	Downward cm mean	(s)	min	max
Pilot	9	26.7	(7.9)	13.5	39.0	18.7	(4.7)	14.0	28.0
Short	5	35.6	(6.7)	26.0	43.0	25.9	(3.3)	21.0	30.0
Tall	8	25.9	(6.8)	16.0	36.0	17.0	(3.7)	11.0	22.0

Table C-4. Visual angle summary statistics for the CH-47C

Subject group	n	Upward cm mean	(s)	min	max	Downward cm mean	(s)	min	max
Pilot	5	44.2	(3.9)	39.0	49.0	16.4	(4.7)	11.0	23.0
Short	6	52.2	(1.0)	51.0	53.0	24.6	(3.4)	20.0	29.0
Tall	8	46.9	(3.7)	42.0	55.0	6.9	(3.7)	-2.0*	10.0

*Eyes below glare shield

Table C-5. Visual angle summary statistics for the AH-1S

Subject group	n	Upward cm mean	(s)	min	max	Downward cm mean	(s)	min	max
Pilot	24	NO UPWARD				18.5	(5.3)	0.0*	25.0
Short	6	VISUAL				8.5	(6.4)	-3.0**	14.0
Tall	10	RESTRICTIONS				7.0	(4.9)	-2.0**	13.0

*Eyes level with glare shield
**Eyes below glare shield

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